RHESSI Imaging Uncertainty Calculation GUI

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1. Required Programs

clean_uncertainty.pro – program used for uncertainty calculation with the Clean algorithm.

mem_njit_uncertainty.pro – program used for uncertainty calculation with MEM_NJIT.

rlp_filename.pro – creates a filename string based on an energy range and time interval of a given image.

find_box_region_index.pro – retrieves indices of pixels inside a user-defined region, used in clean_uncertainty.pro.

get_vis.pro – retrieves visibility structures (raw, edited, and combined-conjugate bags) from a FITS file, used in mem_njit_uncertainty.pro.

hsi_image_monte_carlo.pro – reconstructs a Pixon image (if needed) based on parameters from input image FITS file, calculates an Expected Count Rate (**ECR**), randomizes the ECR, and reconstructs Clean trial maps (the number of maps is specified by the user).

hsi_im_uncertainty.pro – the Graphical User Interface (**GUI**) code.

2. Methodology

Currently, there are four image reconstruction algorithms for RHESSI – Back Projection/Clean (Clean is an extension of **BP**), Pixon, MEM_NJIT, and Visiblity Forward Fit (**VFF**). Only the latter returns uncertainties in source parameters. In fact, VFF's purpose is to calculate said parameters in such a way that the resulting model is consistent with the data. The fitted parameters are then visualized in a map. The process can be repeated a number of times with data randomized with Poisson statistics, leading to standard deviation calculation for each of the fitted parameters, and thus uncertainties in the VFF measurements.

With the other three algorithms, the inverse process occurs – images are reconstructed based on probability maps (**BP**) or constraint to the data (MEM_NJIT and Pixon). Source parameters can then be deduced from the resulting map, though the process is a bit more tricky since an elliptical Gaussian approximation is not made like it is in **VFF**. Though the images are generated in different ways, the uncertainty calculation technique remains the same – the foundation of the sigma calculation is the usage of a Monte Carlo method on RHESSI data, whether it be the ECR (for Clean and Pixon) or visibilities (for MEM_NJIT and **VFF**).

For now, the Monte Carlo method has been utilized in Clean and MEM_NJIT and thus uncertainty programs have been written for the two algorithms. Pixon, since the program is more time-consuming compared to the other 3 algorithms, takes longer to test and its uncertainty code is a work in progress. In both the Clean and MEM_NJIT cases, the randomized data are from the model, i.e. the reconstructed images. For example, the MEM_NJIT maps are converted to model visibilities, then altered, then used to make a new map. A similar process occurs with Clean, though the model ECR is calculated from a Pixon map since Pixon is the most photometrically reliable RHESSI imaging algorithm. New Clean maps are then reconstructed from the randomized ECR.

While the Clean and MEM_NJIT uncertainty scripts have been written as stand-alone IDL programs (clean_uncertainty.pro and mem_njit_uncertainty.pro) that can be executed from the command line interface (**CLI**), a graphical user interface (**GUI**) has been created to assist the user. The rest of this document can be considered a user's manual for the GUI, hsi_im_uncertainty.pro.

3. Usage

The first step is easy – type in "hsi_im_uncertainty" at the IDL command line. The GUI pops up with a number of options, some of which are general, others are algorithm-specific. The user should choose first the algorithm for which they want to calculate uncertainties (MEM_NJIT or Clean), then any irrelevant options are disabled.

3.1. General GUI Options

Image FITS File – required as a starting point, either for model visibility calculation with MEM_NJIT or retrieving imaging parameters for a new Pixon image (from which a new model ECR is calculated). So if MEM_NJIT is selected, the image FITS file *must* contain the MEM_NJIT data and parameters, and for Clean, any image FITS file will work.

Fit Gaussians – as of now, there are 2 methods of finding uncertainties in source parameters, both prompt the user to define where they think the sources are:

1. Fitting Gaussians to the sources and measuring corresponding parameters (e.g. flux, major axis, minor axis, position angle, and position).
2. Taking the data inside the user-defined region and calculating flux, centroid position, standard deviations in the x and y directions (which correspond to source sizes), etc.

Selecting the "Fit Gaussians" option will either call gauss2dfit.pro (for MEM_NJIT) or find "associated Gaussians" for the Clean Components (no fit is done; first and second moments are calculated).

Save Trial Maps – user can choose to save data (trial maps and, in the case of Clean, the ECR) in an effort to save time in a different session of IDL.

Number of Trials – the number of "data randomizations" that are executed, and consequently the number of trial maps that are created.

Use Previous Trial Maps – if selected, the corresponding file (in the text box) should be the file created when the "Save Trial Maps" was used. No imaging is done, the only information used are the saved trial maps and ECR. The user will still be prompted to define source regions.

3.2. Algorithm-Specific Options

3.2.1. MEM_NJIT

Show Progress – shows MEM_NJIT map as it's being reconstructed

Tolerance – number between 0 and 1 that alters convergence criteria. For a stricter convergence (and consequently a slower reconstruction), the user should choose a tolerance lower than the default of 0.03. Conversely, for a "looser" and faster convergence, a higher tolerance can be used, with the caveat that the resulting map will be less constrained to the data.

Visibility FITS File – FITS file containing the visibilities used to make the MEM_NJIT image in the image FITS file. The visibility FITS file is not required; if it is not supplied by the user, the software extracts imaging and visibility information from the image FITS file and generates a new visiblity bag. However, the new bag may contain different roll bin sampling than the initial bag with which the user created the image.

3.2.2. Clean

No Outliers – weeds out any Clean Components that are outside of a 3σ ellipse in the user-defined region, see Dennis & Pernak, 2009 for details.

Use Previous ECR – use Expected Count Rate saved in the file which is supplied by the user (i.e. the file in the text box underneath this option). This save file is identical to the one used in "Previous Trial Maps" since both variables (cln_trial_maps and ECR) are saved in it.

Only the Clean Components are used in the uncertainty calculation, as opposed to the maps that convolve the components with the Clean beam. There are 3 options with the Clean Component method, in order of increasing execution time:

1. Restore trial maps made in a preceding IDL session. The restore file must be specified by the user, but the only other input needed are the user-defined source regions. Optional inputs are to weed out outlier components. Only a computationally quick calculation ensues.

2. Use a saved ECR but make new trial maps. That is to say, use the same model but perform a new set of randomizations. Clean progress windows will pop up while the new maps are being constructed. The user will then be asked to define their source regions.

3. Start from scratch. Imaging parameters are taken from the input image file, then a Pixon image is generated so a new ECR can be extracted. In an effort to conserve time, a provision is written in the code to prevent the images from being any larger than 64 pixels x 64 pixels. Should a change in map dimension be required, the pixel

size is inversely scaled so that an equivalent field of view is represented. Clean maps are then produced, and the user is prompted to define their source regions.

4. ETC.

Included in the zip file with the software are the FITS and save files for a run-through with one event – March 18, 2003, 12:14:00-12:15:00, 50-100 keV.

For analysis of new events, the user is encouraged to use the “Save Trial Maps” option if further analysis is anticipated, as the saved variables and software work with particular naming conventions.

If the user uses previous trial maps in the Clean uncertainty calculation, the image FITS file *must* be the image that was created when the ECR was calculated, which is one of the reasons the user is advised to save the trial maps if its their first run on an event. Pixon images are automatically saved (see hsi_image_monte_carlo.pro), but the corresponding trial maps are not unless the user specifies.